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published in
Journal of Physical Activity & Health
2008

DOI (link to publisher)
10.1123/jpah.5.6.815

document version
Publisher's PDF, also known as Version of record

Journal of Physical Activity and Health, 2008, 5, 815-829

Associations Between Aerobic and Muscular Fitness and Cardiovascular Disease Risk: The Northern Ireland Young Hearts Study

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Background: It is not clear what the relative contribution is of specific components of physical fitness (aerobic and muscular) to cardiovascular disease (CVD) risk. We investigated associations between aerobic fitness (endurance) *and* muscular fitness (power) and CVD risk factors. ***Methods:*** Data were obtained from the Young Hearts project, a representative sample of 12- and 15-year-old boys and girls from Northern Ireland (N = 2016). Aerobic fitness was determined by the 20-m shuttle run test, muscular fitness by the Sargent jump test. CVD risk factors included sum of skinfolds, systolic and diastolic blood pressure, serum total cholesterol (TC), HDL cholesterol, and TC:HDL ratio. Several linear regression analyses were conducted for 4 age and gender groups separately, with the risk factor as the outcome variable. ***Results:*** Significant associations between aerobic fitness and a healthy CVD risk profile were found. These observed relationships were independent of power, whereas the (few) relationships between muscular fitness and the risk factors were partly explained by endurance. ***Conclusions:*** Tailored, preventive strategies during adolescence, incorporating endurance rather than power sports, could be encouraged to help prevent CVD. This is important because existing studies propose that healthiness during adulthood is founded on healthiness in adolescence.

Keywords: endurance, power, cardiovascular disease risk factors, adolescents

Although the relationship between general physical fitness and cardiovascular morbidity and mortality is well established in adults, adolescents, and children,[1–3] it is much less clear (especially in adolescents) what the relative contribution is of 2 specific components of physical fitness: aerobic and muscular fitness.

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Many studies show that low aerobic fitness, to a great extent, increases cardiovascular disease risk (CVD).[4] However, more recently, it has also been postulated that an individual's susceptibility to CVD risk might be influenced by *both* their aerobic fitness and their muscular fitness,[5] in part genetically based on the proportion of fast and slow muscle fibers[6] of the individual. A high proportion of slow muscle fibers (Type I) correlates positively with favorable CVD risk profiles.[7]

To date, no study has examined the relationship between both aerobic fitness *and* muscular fitness in relation to CVD risk in adolescents. CVD risk is now more than ever an important topic for investigation because the World Health Organization[8] estimates that currently 16.7 million deaths (almost 30% of total deaths worldwide) are a result of the various forms of CVD, many of which could have been prevented by taking action on primary risk factors such as low fitness, unhealthy diet, physical inactivity, and smoking. Moreover, many studies[9] have revealed that the foundations of a healthy lifestyle are laid down in childhood and adolescence, making this stage of the life course particularly relevant for the formation of successful preventive strategies.

Therefore, the purpose of the current study was to investigate the association between aerobic fitness and muscular fitness, and cardiovascular disease risk factors in a population of adolescents.

Materials and Methods

The Young Hearts (YH2000) project was a cross-sectional study carried out in the year 2000. Approximately 500 subjects in each of 4 age (12 and 15 years old) and gender (boys and girls) groups were recruited through postprimary schools across Northern Ireland; the number of children in each subgroup was proportional to the corresponding population number. The YH2000 is a representative sample of the population in Northern Ireland. In the current study, 36 schools took part. The YH2000 resembles the study design of the first Young Hearts Study (YH1), a study aiming to evaluate (longitudinally) the status of major modifiable coronary risk factors within the adolescent population of Northern Ireland. Furthermore, detailed information about this study can be found elsewhere.[10]

Ethical approval was obtained from the Research Ethics Committee of the Queen's University of Belfast, and written informed consent was obtained from each participant, as well as from the parent or guardian. Screening took place at the participating schools during normal school hours. For logistical reasons, all tests were carried out in the same order for each participating child, with the muscular fitness tests always preceding the aerobic fitness tests by approximately 2 hours to ensure valid measurements.

Fitness Components

Aerobic fitness (endurance) was measured by the 20-m shuttle run test[11] in which the number of completed laps was converted to a predicted maximal oxygen uptake score (VO_{2max}). This test has proven validity in children and adolescents.[11]

Muscular fitness (power) was measured by the Sargent jump test[12] in which the child was asked to jump up vertically from a standing position. The jumping height was recorded to the nearest centimeter as the best of 2 jumps. The jump test is well known and has been used in many observational studies,[13] as well as in experimental settings,[14] and there are some studies that compare the test to other measures of muscular fitness.[15] Although the jump test is applied extensively in current research, a full validation study for the adolescent population seems to be unavailable in the current literature.

Cardiovascular Disease Risk Factors

Skinfold thicknesses were determined according to the method described by Durnin and Rahaman[16] from 4 sites (biceps, triceps, subscapular, and suprailiac). A Hawksly random-zero sphygmomanometer was used to measure blood pressure twice at the right arm in a sitting position after a resting period of at least 5 minutes. Systolic blood pressure was based on the means of 2 recordings of Korotkoff phase I; diastolic blood pressure was based on the means of 2 recordings of phase V for 15-year-olds and phase IV for 12-year-olds.[17]

Nonfasting blood samples were drawn from the antecubital vein, with total cholesterol and high density cholesterol (HDL) values estimated by an enzymatic technique (CHOD-PAP, Boehringer Mannheim, Mannheim, Germany) and phosphotungstic magnesium reagents, respectively. All assays were performed in a laboratory conforming to World Health Organization standards.

Covariates

During a medical examination, weight, height, and sexual maturity according to the Tanner criteria[18] were determined by a pediatrician.

Socioeconomic status was determined from occupational information provided by the parents or guardians of the child. This information was then classified according to the Office of Population Censuses and Surveys[19] and further categorized into 4 groups.

A questionnaire on everyday physical activities was the basis for individually calculated total activity scores. Each answer was coded according to frequency, intensity, and duration, appropriately weighted, from which the total activity scores (1 to 100 points) were computed. The questionnaire, designed and validated exclusively for the first Young Hearts Study, has been described elsewhere.[20]

Statistical Analyses

Statistical analyses were conducted using the SPSS 14 software package. All 4 age and gender groups were analyzed separately to ensure optimal correction for differences in biological maturity and correspond with previous publications from the Northern Ireland Young Hearts Studies. Characteristics of the study sample were described by means and their standard deviations, with all variables meeting the normality assumption. To assess the relationship between several variables of interest, Pearson product moment correlation coefficients (r) were calculated. Associations between the CVD risk factors and aerobic and muscular fitness were analyzed with several linear regression analyses, with the CVD risk factor as the outcome variable. First, a (crude) analysis was performed in which aerobic and muscular fitness were individually related to the CVD risk factors, correcting only for sexual maturity, socioeconomic status, and physical activity scores. Second, an (adjusted) analysis was carried out in which both aerobic and muscular fitness were added to the crude regression model, hereby analyzing aerobic and muscular fitness *together* in relation to the CVD risk factors. This enabled us to study the *corrected* effect of the separate fitness components on the selected CVD risk factors. Third, the possible interaction between both measurements of fitness was investigated. To do so, an interaction term was computed (by multiplying aerobic fitness by muscular fitness), which was then added to the adjusted linear regression model.

Results

Table 1 shows the descriptive data for the main variables measured. Pearson product moment correlations are shown in Table 2. The correlations ranged from weak (eg, correlations between the hand grip strength and fitness) to strong (eg, correlations between weight and fitness). The correlations between variables added to the same regression models were of acceptable values to reduce the possibility of multicolinearity to a minimum.

Tables 3 and 4 show the results of the linear regression analyses for the relationships between aerobic and muscular fitness and CVD risk factors.

From Tables 3 and 4 it is clear that associations with CVD risk factors are noticeably different for aerobic and muscular fitness. On the whole, significant associations between aerobic fitness and a healthy CVD risk profile were observed for all age and gender groups. Moreover, most (crude) associations seem to survive further correction for muscular fitness. However, the strength of these associations is somewhat different between the 4 groups. They were strongest for the younger boys, among whom significant associations were found for all CVD risk factors. Results were quite similar for the older girls. For the 2 other subgroups, associations were only slightly weaker, but not all risk factors proved to be significantly associated with aerobic fitness.

Associations between muscular fitness and CVD risk factors were very different. Although muscular fitness was also found to be associated with a healthy risk profile, only a few statistically significant associations were apparent. Most of these associations, however, did not survive further correction for aerobic fitness. Strength of association was once more strongest for the younger boys, followed by the older girls, and again weaker for the other 2 subgroups.

No significant interactions between aerobic and muscular fitness were found within the YH2000 study (P values for the interaction terms ranged from .08 to .96).

Table 1 Means (SD) of the Variables of Interest

	Boys		Girls	
	12 years (n = 532)	15 years (n = 486)	12 years (n = 515)	15 years (n = 483)
Height (mm)	1523.1 (76.60)	1719.7 (79.10)	1537.2 (71.21)	1625.3 (57.52)
Weight (kg)	45.32 (10.43)	61.13 (11.73)	48.22 (10.69)	58.11 (10.07)
Total skinfolds (mm)	39.81 (22.40)	33.74 (19.08)	49.58 (21.04)	54.12 (21.00)
Systolic blood pressure (mmHg)	102.88 (11.64)	113.23 (12.77)	104.14 (12.11)	109.89 (11.06)
Diastolic blood pressure (mmHg)	59.10 (8.72)	62.45 (8.40)	60.42 (8.62)	64.49 (8.64)
Total cholesterol (mmol/l)	4.19 (0.69)	3.72 (0.64)	4.20 (0.71)	4.03 (0.64)
HDL (mmol/l)	1.35 (0.32)	1.20 (0.273)	1.32 (0.28)	1.36 (0.30)
TC:HDL	3.25 (0.83)	3.25 (0.92)	3.31 (0.82)	3.09 (0.84)
VO_{2max} [ml/(kg/min)]	46.53 (6.40)	53.61 (6.87)	39.81 (6.87)	41.25 (6.92)
Jumping height (cm)	39.75 (6.71)	48.99 (7.43)	36.55 (5.99)	37.76 (6.14)
Handgrip strength (kg)	20.26 (4.53)	34.09 (7.02)	18.90 (4.25)	24.22 (4.41)
Total activity scores (1–100)	18.33 (9.04)	15.65 (8.48)	12.88 (7.94)	10.61 (7.53)

Abbreviations: HDL, high density lipoprotein; TC, total cholesterol.

Discussion

Our study investigated the associations between aerobic and muscular fitness and major CVD risk factors in a population of adolescents from Northern Ireland. To our knowledge, the current study is the first to take *both* aerobic and muscular fitness into account in investigating their relationship with CVD risk factors in young adolescents. In sum, the observed relationships between aerobic fitness and CVD risk factors are independent of muscular fitness, whereas the (few) relationships between muscular fitness and the CVD risk factors are partly explained by aerobic fitness. Moreover, neither aerobic fitness nor muscular fitness enforces each other's association with CVD risk factors. The associations were

Table 2 Range of Pearson Product Moment Correlations (*r*), Computed Separately for the 4 Subgroups

	VO_{2max} [ml/(kg/min)]	Jump test (cm)	Hand grip (kg)	Physical activity (0–100)	Weight (kg)	Sum of 4 skinfolds (mm)	Tanner criteria (1–5)
VO_{2max} [ml/(kg/min)]	*1.00*	0.30 to 0.38	0.12 to 0.17	0.24 to 0.36	–0.17 to –0.31	–0.35 to –0.50	–0.10 to 0.13
Jump test (cm)	0.30 to 0.38	*1.00*	0.25 to 0.38	0.10 to 0.21	–0.13 to 0.04	–0.35 to –0.20	–0.08 to 0.25
Hand grip (kg)	0.12 to 0.17	0.25 to 0.38	*1.00*	0.04 to 0.27	0.40 to 0.58	0.15 to 0.26	0.20 to 0.55
Physical activity (1–100)	0.24 to 0.36	0.10 to 0.21	0.04 to 0.27	*1.00*	–0.07 to 0.11	–0.07 to –0.01	–0.10 to 0.08
Weight (kg)	–0.17 to –0.31	–0.13 to 0.04	0.40 to 0.58	–0.07 to 0.11	*1.00*	0.76 to 0.81	0.39 to 0.53
Sum of 4 skinfolds (mm)	–0.35 to –0.50	–0.35 to –0.20	0.15 to 0.26	–0.07 to –0.01	0.76 to 0.81	*1.00*	0.08 to 0.36
Tanner criteria (1–5)	–0.10 to 0.13	–0.08 to 0.25	0.20 to 0.55	–0.10 to 0.08	0.39 to 0.53	0.08 to 0.36	*1.00*

Table 3 Regression Coefficients (95% CI) and *P* Values for the Association Between Aerobic and Muscular Fitness and Cardiovascular Disease Risk Factors for 12- and 15-Year-Old Boys

	12-year-old boys				15-year-old boys			
	Aerobic fitness		Muscular fitness		Aerobic fitness		Muscular fitness	
SSF								
crude[a]	–1.871 (–2.177 to –1.565)	$P < .001$	–1.398 (–1.708 to –1.089)	$P < .001$	–1.374 (–1.656 to –1.092)	$P < .001$	–0.650 (–0.934 to –0.367)	$P < .001$
adjusted[b]	–1.539 (–1.856 to –1.221)	$P < .001$	–0.866 (–1.167 to –0.565)	$P < .001$	–1.277 (–1.566 to –0.988)	$P < .001$	–0.353 (–0.619 to –0.086)	$P = .010$
SBP								
crude[a]	–0.300 (–0.474 to –0.125)	$P = .001$	–0.123 (–0.290 to 0.044)	$P = .150$	–0.200 (–0.402 to 0.002)	$P = .052$	0.095 (–0.092 to 0.282)	$P = .318$
adjusted[b]	–0.291 (–0.478 to –0.104)	$P = .002$	–0.022 (–0.200 to 0.155)	$P = .804$	–0.242 (–0.450 to –0.034)	$P = .027$	0.151 (–0.041 to 0.344)	$P = .122$
DBP								
crude[a]	–0.247 (–0.382 to –0.112)	$P < .001$	–0.188 (–0.317 to –0.060)	$P = .004$	–0.087 (–0.219 to 0.046)	$P = .200$	–0.007 (–0.130 to 0.115)	$P = .909$
adjusted[b]	–0.201 (–0.346 to –0.057)	$P = .006$	–0.119 (–0.256 to 0.018)	$P = .089$	–0.090 (–0.228 to 0.047)	$P = .196$	0.014 (–0.113 to 0.141)	$P = .828$

(continued)

Table 3 *(continued)*

	12-year-old boys				15-year-old boys			
	Aerobic fitness		Muscular fitness		Aerobic fitness		Muscular fitness	
TC								
crude[a]	–0.015 (–0.026 to –0.004)	$P = .008$	–0.011 (–0.021 to 0.000)	$P = .042$	–0.022 (–0.033 to –0.012)	$P < .001$	–0.001 (–0.010 to 0.009)	$P = .912$
adjusted[b]	–0.012 (–0.024 to –0.001)	$P = .039$	–0.006 (–0.017 to 0.005)	$P = .255$	–0.024 (–0.034 to –0.013)	$P < .001$	0.005 (–0.005 to 0.015)	$P = .313$
HDL								
crude[a]	0.009 (0.004 to 0.014)	$P < .001$	0.005 (0.000 to 0.010)	$P = .038$	0.005 (0.000 to 0.009)	$P = .034$	0.001 (–0.003 to 0.005)	$P = .535$
adjusted[b]	0.008 (0.003 to 0.013)	$P = .003$	0.002 (–0.003 to 0.007)	$P = .404$	0.005 (0.000 to 0.009)	$P = .043$	0.000 (–0.004 to 0.004)	$P = .935$
TC:HDL								
crude[a]	–0.037 (–0.050 to –0.024)	$P < .001$	–0.022 (–0.034 to –0.010)	$P < .001$	–0.035 (–0.049 to –0.021)	$P < .001$	–0.005 (–0.018 to 0.008)	$P = .467$
adjusted[b]	–0.033 (–0.046 to –0.019)	$P < .001$	–0.011 (–0.023 to 0.002)	$P = .098$	–0.036 (–0.051 to –0.021)	$P < .001$	0.004 (–0.010 to 0.017)	$P = .601$

Abbreviations: SSF, sum of 4 skinfolds; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; HDL, high density lipoprotein.

[a] Crude: correcting for sexual maturation (continuous), social class (categorical), and physical activity scores (continuous).

[b] Adjusted: also correcting for either muscular fitness or aerobic fitness.

Table 4 Regression Coefficients (95% CI) and *P* Values for the Association Between Aerobic and Muscular Fitness and Cardiovascular Disease Risk Factors for 12- and 15-Year-Old Girls

	12-year-old girls				15-year-old girls			
	Aerobic fitness		Muscular fitness		Aerobic fitness		Muscular fitness	
SSF								
crude[a]	−1.028 (−1.299 to −0.756)	$P < .001$	−0.875 (−1.190 to −0.560)	$P < .001$	−1.088 (−1.367 to −0.808)	$P < .001$	−0.878 (−1.183 to −0.573)	$P < .001$
adjusted[b]	−0.856 (−1.147 to −0.564)	$P < .001$	−0.506 (−0.834 to −0.178)	$P = .003$	−0.918 (−1.207 to −0.630)	$P < .001$	−0.577 (−0.882 to −0.271)	$P < .001$
SBP								
crude[a]	−0.109 (−0.274 to 0.055)	$P = .192$	−0.002 (−0.188 to 0.184)	$P = .982$	−0.231 (−0.398 to −0.064)	$P = .007$	−0.176 (−0.353 to 0.002)	$P = .053$
adjusted[b]	−0.127 (−0.305 to 0.051)	$P = .162$	0.052 (−0.184 to 0.253)	$P = .609$	−0.199 (−0.374 to −0.023)	$P = .027$	−0.110 (−0.296 to 0.075)	$P = .243$
DBP								
crude[a]	−0.157 (−0.280 to −0.035)	$P = .012$	−0.083 (−0.222 to 0.056)	$P = .240$	−0.270 (−0.401 to −0.139)	$P < .001$	−0.242 (−0.381 to −0.103)	$P = .001$
adjusted[b]	−0.151 (−0.284 to −0.018)	$P = .026$	−0.018 (−0.168 to 0.131)	$P = .808$	−0.220 (−0.357 to −0.084)	$P = .002$	−0.170 (−0.314 to −0.025)	$P = .022$

(continued)

Table 4 *(continued)*

	12-year-old girls				15-year-old girls			
	Aerobic fitness		Muscular fitness		Aerobic fitness		Muscular fitness	
TC								
crude[a]	–0.014 (–0.025 to –0.003)	*P* = .012	–0.010 (–0.023 to 0.002)	*P* = .099	–0.004 (–0.014 to 0.006)	*P* = .463	0.000 (–0.011 to 0.010)	*P* = .937
adjusted[b]	–0.012 (–0.024 to 0.000)	*P* = .042	–0.005 (–0.018 to 0.008)	*P* = .455	–0.004 (–0.015 to 0.007)	*P* = .457	0.001 (–0.010 to 0.012)	*P* = .876
HDL								
crude[a]	0.005 (0.001 to 0.010)	*P* = .017	0.001 (–0.004 to 0.006)	*P* = .604	0.008 (0.003 to 0.013)	*P* = .001	0.003 (–0.002 to 0.008)	*P* = .233
adjusted[b]	0.006 (0.001 to 0.010)	*P* = .018	–0.001 (–0.006 to 0.004)	*P* = .675	0.008 (0.003 to 0.013)	*P* = .002	0.000 (–0.005 to 0.006)	*P* = .860
TC:HDL								
crude[a]	–0.026 (–0.038 to –0.013)	*P* < .001	–0.013 (–0.027 to 0.001)	*P* = .071	–0.020 (–0.033 to –0.007)	*P* = .003	–0.003 (–0.017 to 0.011)	*P* = .640
adjusted[b]	–0.025 (–0.038 to –0.011)	*P* < .001	–0.003 (–0.018 to 0.013)	*P* = .740	–0.021 (–0.035 to –0.007)	*P* = .003	0.004 (–0.011 to 0.018)	*P* = .631

Abbreviations: SSF, sum of 4 skinfolds; SBP, systolic blood pressure; DBP, diastolic blood pressure; TC, total cholesterol; HDL, high density lipoprotein.
[a] Crude: correcting for sexual maturation (continuous), social class (categorical), and physical activity scores (continuous).
[b] Adjusted: also correcting for either muscular fitness or aerobic fitness.

investigated for the young and old boys and girls separately to correct optimally for biological maturation. The effects were noticeably different for all 4 groups, justifying our choice for stratification. In addition, presenting the results for all 4 groups separately is in line with previous publications with YH data,[10,21] making comparison of these results possible and straightforward.

Aerobic Fitness

The fact that our study showed weak to moderate associations between aerobic fitness and a healthy CVD risk profile across all age and gender groups is in line with existing literature.[4] When examining the association with aerobic fitness and the CVD risk factors separately, we found the strongest association between skinfolds and aerobic fitness within the YH2000 study. This is fully in agreement with existing literature, which also shows strong inverse associations between aerobic fitness and fatness[1,22] in various study populations.

Regarding systolic and diastolic blood pressure, we found weak inverse associations with aerobic fitness. Although there are observational cohort studies,[21] the available research on this topic relates mainly to training (intervention) studies covering various study populations ranging from school children[23] to adults[24] and the elderly.[25] Most studies do find inverse associations between aerobic exercise/fitness and blood pressure, which is consistent with our findings. A meta-analysis, conducted by Whelton et al in 2002,[26] also showed beneficial effects of aerobic exercise on blood pressure, both in normotensive as well as in hypertensive persons. However, it must be noted that many studies focus on aerobic *exercise*, as opposed to aerobic *fitness*. Nevertheless, aerobic exercise generally improves VO_{2max}, implying an improvement in aerobic fitness.

When looking at the associations between aerobic fitness and cholesterol levels, our study revealed small inverse associations with total cholesterol levels and TC:HDL across all 4 groups and smaller (positive) associations with HDL cholesterol. The existing literature, again, mainly focuses on training studies,[27] but cross-sectional studies comparable to ours also exist.[22] In general, we found similar associations to those reported above (ie, an increase in aerobic fitness increases HDL cholesterol level and decreases total cholesterol levels).

Muscular Fitness

Regarding the relationship between CVD risk factors and muscular fitness, we found the strongest associations across all 4 groups for skinfolds (results were comparable to those found for aerobic fitness). The literature on this relationship is rather ambiguous. In general, beneficial effects of resistance training on body composition or body fat are reported,[28,29] although comparisons between studies are somewhat difficult because they are mainly intervention studies with different intervention strategies. For instance, Banz et al[28] only focused on the *type* of training, whereas Ross et al[29] also included a dietary component in their intervention, making it difficult to identify whether the loss of body fat was solely a result of the (resistance) training.

When looking at the results relating to blood pressure, again, we found inverse associations across all age and gender groups, with associations being strongest for the older girls. Current research implies that weightlifters, who possess high muscular fitness as a result of their training, have either elevated,[5] similar,[30] or even lower[31] arterial blood pressure values compared with their untrained controls. It must, however, be noted that most studies are training studies among adults (mostly men) and do not assess the associations in young adolescents.

When looking at the associations between muscular fitness and cholesterol levels, our study demonstrated very slight inverse associations for total cholesterol levels and TC:HDL and smaller positive associations for HDL cholesterol. Although few studies are available for comparison, an interesting randomized controlled trial was conducted by LeMura et al.[32] They compared a resistance training group with an aerobic training group, among others. They found no beneficial effects of resistance training on cholesterol levels within a group of 20-year-old women. These results are comparable to our findings, although our study population is slightly younger than the subjects participating in the trial.

The results of the current study regarding muscular fitness and CVD risk are difficult to interpret. For comparison, observational studies comparable to ours are scarce and intervention studies are inconclusive, indicating an opportunity for researchers involved in observational cohort studies on (muscular) fitness and (cardiovascular) health. It is interesting to see that observational research looking into the complex concept of fitness in relation to CVD risk has been mainly focusing on *aerobic* fitness and not so much on *muscular* fitness.

Further Comments

A possible explanation for our findings is that subjects in the YH2000 study are mainly involved in physical activities that stimulate their aerobic fitness rather than their muscular fitness. From detailed questionnaires regarding sports participation (data not shown), it is clear that the subjects generally favored team endurance sports, with soccer, hockey, and netball alone comprising 54% of all sports activities. The fact that the observed associations (however weak) between muscular fitness and CVD risk are partly explained by aerobic fitness is, therefore, not surprising, particularly given findings that resistance training (ie, improving one's muscular fitness) might improve aerobic fitness as well.[33] The small amount of power-sports participation within the YH2000 might also explain our findings with regard to the possible enforcing effects aerobic fitness and muscular fitness might have on each other. We found no interaction between the 2 measurements of fitness, which is in accordance with some studies,[34] although other studies do suggest an enforcing effect[35] or even an inhibiting effect.[36] The concept behind this is that the proportion of fast and slow muscle fibers influences the magnitude of CVD risk.[5] This is based on the findings that power athletes generally possess high levels of fast-twitch muscle fibers, whereas endurance athletes have a high proportion of slow-twitch muscle fibers. Fast-twitch muscle fibers have the lowest volumes of mitochondria and oxidative enzymes, whereas slow-twitch muscle fibers contain more mitochondria and use fatty acids for energy supply, thereby conferring resistance to obesity.[6]

The results of our study should, however, be interpreted with some caution. For example, it is acknowledged that the level of (biological) maturity influences aerobic fitness, explaining to a degree the variance in aerobic fitness among adolescents of the same gender and age.[37] To take these findings into account, we corrected for sexual maturation in all our models. However, level of sexual maturation was measured by means of the Tanner criteria, which in part are based on subjective observations, and not, for instance, on blood hormone concentrations. Nevertheless, our study population is quite large (N = 2016), and the Tanner criteria have been validated against objective measures of sexual maturation,[38] reducing the distorting effect to a minimum.

Furthermore, for measuring the level of muscular fitness, we used the Sargent jump test, which reflects muscular fitness in the upper legs. Another measurement performed in our study was the hand grip test, which has also been shown to be a good predictor of overall muscular fitness.[39] The hand grip test is, however, a static test, whereas the jump test is a dynamic one (Pearson product moment correlation between the two ranges from .25 to .38 across the groups, see Table 2). In additional analyses, we replaced the jump test results with the hand grip test results. The resulting associations between aerobic and muscular fitness and CVD risk factors, however, were quite similar (data not shown).

Implications

The results of our study indicate opportunities for targeted preventive medicine. Based on the observed associations between aerobic fitness and the CVD risk factors, opportunities for preventive strategies during adolescence, incorporating endurance sports rather than power sports, could be encouraged to help prevent CVD. Moreover, it is also shown that on the whole, adolescents seem to prefer endurance sports over power sports. Early, successful prevention programs are also important in light of previous studies[9,40] proposing that a healthy lifestyle during adulthood is founded by a healthy lifestyle in (early) adolescence.

In conclusion, we found associations between aerobic fitness and a healthy CVD risk profile, which proved to be independent of muscular fitness, whereas associations between muscular fitness and selected CVD risk factors were partly explained by aerobic fitness. Moreover, neither aerobic fitness nor muscular fitness interacts with each other's association with CVD risk factors.

Acknowledgments

The Young Hearts project was funded by the British Heart Foundation and the Wellcome Trust. None of the authors have any financial interests or conflicts of interests.

References

1. Andersen LB, Haraldsdottir J. Coronary heart disease risk factors, physical activity and fitness in young Danes. *Med Sci Sports Exerc*. 1995;27:158–163.
2. Blair SN, Kampert JB, Kohl HW, Barlow CE, Macera CA, Paffenbarger RSJ. Influences of cardiorespiratory fitness and other predictors on cardiovascular disease and all-cause mortality in men and women. *JAMA*. 1996;276:205–210.
3. Froberg K, Andersen LB. Mini review: physical activity and fitness and its relations to cardiovascular disease risk factors in children. *Int J Obes (Lond).* 2005;29(suppl 2):S34–S39.

4. Carnethon MR, Gulati M, Greenland P. Prevalence and cardiovascular disease correlates of low cardiorespiratory fitness in adolescents and adults. *JAMA*. 2005;294:2981–2988.
5. Kujala UM. Does training adversely affect long-term health. *Lancet*. 2005;366:S55–S56.
6. Wang YX, Zhang CL, Yu RT, et al. Regulation of muscle fiber type and running endurance by PPARdelta. *PLoS Biol*. 2004;2:e294.
7. Wade AJ, Marbut MM, Round JM. Muscle fibre type and aetiology of obesity. *Lancet*. 1990;335:805–808.
8. World Health Organization. *Preventing Chronic Diseases: A Vital Investment. WHO Global Report*. Geneva, Switzerland: World Health Organization; 2005.
9. Ferreira I, Twisk JWR, van Mechelen W, Kemper HCG. Current and adolescent levels of cardiopulmonary fitness are related to large artery properties at age 36: the Amsterdam Growth and Health Longitudinal Study. *Eur J Clin Invest*. 2002;32:723–731.
10. Boreham C, Savage J, Primrose D, Cran G, Strain J. Coronary risk factors in school children. *Arch Dis Child*. 1993;68:182–186.
11. Boreham CA, Palikzka VJ, Nichols AK. A comparison between the PWC170 and 20-MST tests of aerobic fitness in adolescent school children. *J Sports Med Phys Fitness*. 1990;30:19–23.
12. Sargent DA. The physical test of man. *Am Phys Educ Rev.* 1921;25:188–194.
13. Kemper H. *Amsterdam Growth and Health Longitudinal Study (AGAHLS): A 23-Year Follow-Up From Teenager to Adult about Lifestyle and Health*. Amsterdam: Karger; 2004.
14. Markovic G. Does plyometric training improve vertical jump height? a meta-analytical review. *Br J Sports Med*. 2007;41:349–355.
15. van Praagh E. Anaerobic fitness tests: what are we measuring? *Med Sport Sci.* 2007;50:26–45.
16. Durnin JVG, Rahaman MM. The assessment of the amount of fat in the human body from measurements of skinfold thicknesses. *Br J Nutr.* 1967;21:681–689.
17. Petrie JC, O'Brien ET, Littler WAW, De Swiet M. Recommendations on blood pressure measurement. *BMJ*. 1986;293:611–615.
18. Tanner JM. Growth and endocrinology of the adolescent. In: Gardner L, ed. *Endocrine and Disease of Childhood.* Philadelphia, PA: WB Saunders; 1975:14–64.
19. Office of Population Censuses and Surveys. *Standard Occupational Classification.* Vol 1, 2, 3. London, UK: Government Statistical Service; 1990.
20. Riddoch CJ, Savage JM, Murphy N, Cran G, Boreham C. Long term health implications of fitness and physical activity patterns. *Arch Dis Child.* 1991;66:1426–1433.
21. Boreham C, Twisk J, Murray L, Savage J, Strain J, Cran G. Fitness, fatness, and coronary heart disease risk in adolescents: the Northern Ireland Young Hearts Project. *Med Sci Sports Exerc*. 2001;33:270–274.
22. Lee SJ, Arslanian SA. Cardiorespiratory fitness and abdominal adiposity in youth. *Eur J Clin Nutr*. 2007;61:561–565.
23. McMurray RG, Harrell JS, Bangdiwala SI, Bradley CB, Deng S, Levine A. A school-based intervention can reduce body fat and blood pressure in young adolescents. *J Adolesc Health*. 2002;31:125–132.
24. Wilmore JH, Stanforth PR, Gagnon J, et al. Heart rate and blood pressure changes with endurance training: the HERITAGE Family Study. *Med Sci Sports Exerc*. 2001;33:107–116.
25. Kelley G, Sharpe Kelley K. Aerobic exercise and resting blood pressure in older adults: a meta-analytic review of randomized controlled trials. *J Gerontol A Biol Sci Med Sci*. 2001;56:M298–M303.
26. Whelton SP, Chin A, Xin X, He J. Effect of aerobic exercise on blood pressure: a meta-analysis of randomized, controlled trials. *Ann Intern Med*. 2002;136:493–503.

27. Kelley GA, Kelley KS. Aerobic exercise and lipids and lipoproteins in children and adolescents: a meta-analysis of randomized controlled trials. *Atherosclerosis*. 2007;191:447–453.
28. Banz WJ, Maher MA, Thompson WG, et al. Effects of resistance versus aerobic training on coronary artery disease risk factors. *Exp Biol Med*. 2003;228:434–440.
29. Ross R, Rissanen H, Pedwek J, Clifford P, Shagge L. Influence of diet and exercise on skeletal muscle and visceral adipose tissue in men. *J Appl Physiol*. 1996;81:2445–2455.
30. van Hoof R, Macor F, Lijnen P, et al. Effect of strength training on blood pressure measured in various conditions in sedentary men. *Int J Sports Med*. 1996;17:415–422.
31. Hurley BJ, Hagberg JM, Goldberg AP, et al. Resistance training can reduce coronary risk factors without altering VO2 max or percent body fat. *Med Sci Sports Exerc*. 1988;20:150–154.
32. LeMura LM, von Duvillard SP, Andreacci J, Klebez JM, Chelland SA, Russo J. Lipid and lipoprotein profiles, cardiovascular fitness, body composition, and diet during and after resistance, aerobic and combination training in young women. *Eur J Appl Physiol*. 2000;82:451–458.
33. Vincent KR, Braith RW, Feldman RA, Kallas H, Lowenthal DT. Improved cardiorespiratory endurance following 6 months of resistance exercise in elderly men and women. *Arch Intern Med*. 2002;162:673–678.
34. Sale DG, MacDougall JD, Jacobs I, Garner S. Interaction between concurrent strength and endurance training. *J Appl Physiol*. 1990;68:260–270.
35. Hickson RC, Dvorak BA, Gorostiaga EM, Kurowski TT, Foster C. Potential for strength and endurance training to amplify endurance performance. *J Appl Physiol*. 1988;65:2285–2290.
36. Leveritt M, Abernethy PJ, Barry BK, Logan PA. Concurrent strength and endurance training. *Sports Med*. 1999;28:413–427.
37. Mota J, Guerra S, Leandro C, Pinto A, Ribero JC, Duarte JA. Association of maturation, sex, and body fat in cardiorespiratory fitness. *Am J Hum Biol*. 2002;14:707–712.
38. Morris NM, Udry JR. Validation of a self-administered instrument to assess stage of adolescent development. *J Youth Adolesc*. 1980;9:271–280.
39. Innes EV. Handgrip strength testing: a review of the literature. *Aust Occup Ther J*. 1999;46:120.
40. Serdula MK, Ivery D, Coates RJ, Freedman DS, Williamson DF, Byers T. Do obese children become obese adults? a review of the literature. *Prev Med*. 1993;22:167–177.